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A REGIONAL APPROACH TO THE WABIGOON–QUETICO BELTS AND ITS BEARING ON EXPLORATION IN NORTHWESTERN ONTARIO

By

W. O. MACKASEY, C. E. BLACKBURN AND N. F. TROWELL

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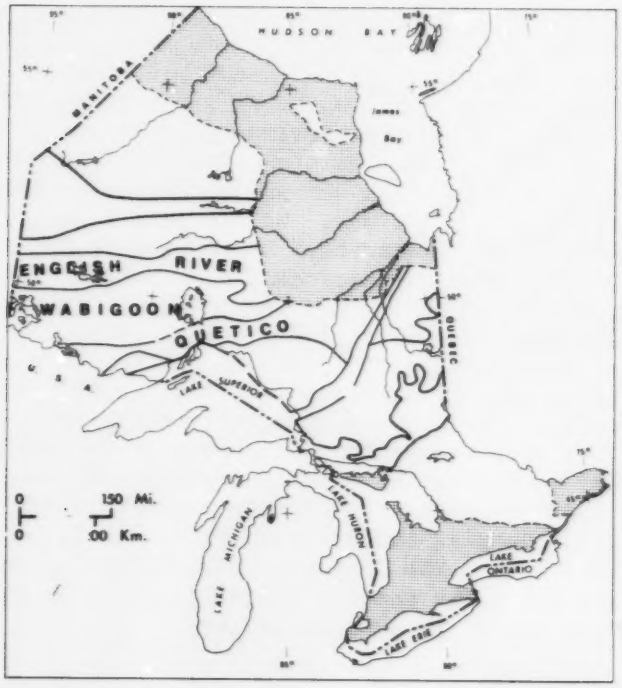
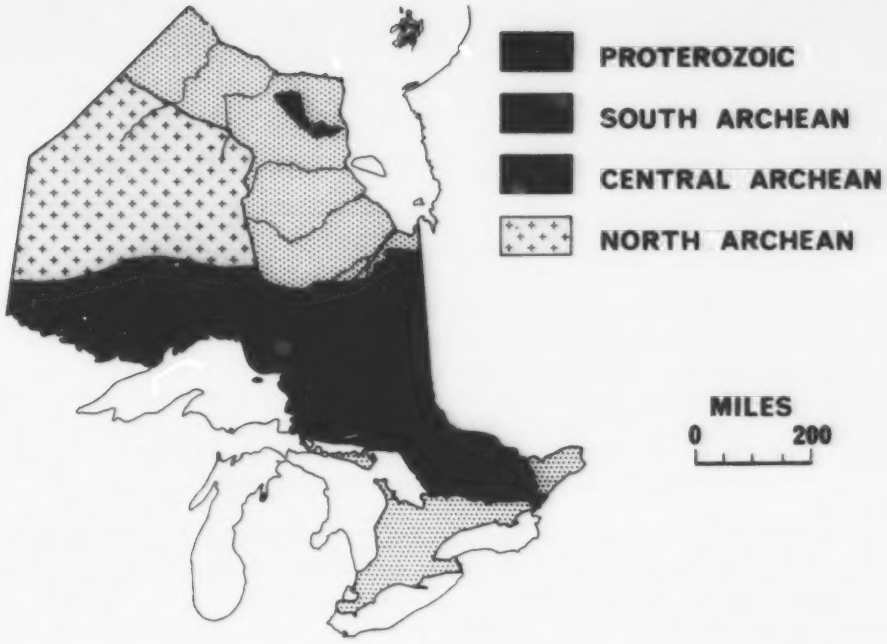
PROLOGUE

The purpose of this paper is to review and focus attention on the mineral potential of Northwestern Ontario in a manner similar to that done by Riley et al. 1971. The major part of this paper deals with the geology and mineral deposits associated with the Wabigoon and Quetico Belts and a part of the English River Belt. Figure 1, adapted from the geological map of Ontario (Ayres et al. 1971), shows the breakdown of the Precambrian shield into its component belts and structural zones.

The information presented here formed a paper that was presented by the authors at the 42nd Annual Meeting and Convention of the Prospectors and Developers Association, Toronto, in March 1974.



1. Map of Ontario showing the English River, Wabigoon, and Quetico Belts in relation to other structural zones and belts. Stipple indicates Phanerozoic rocks.



2. Organizational map of the Precambrian Geology Section, Geological Branch, Ontario Division of Mines, showing geographical areas of the subsections.

INTRODUCTION

The day of the individual government geologist working entirely on his own in Ontario is now at an end. We are at a stage in the mapping of Ontario where most of the "greenstone" belts have been outlined. It is now necessary to be able to look beyond the boundaries of the conventional two township map-area to see if there is continuity from not only one map-area to another but from district to district.

The Precambrian Geology Section, as it is now called, has been set up within the Geological Branch of the Ontario Division of Mines and consists of subsections that will more effectively be able to work in the gathering, assessing, and interpretation of data concerning the Precambrian geology of Ontario. These subsections have a primary responsibility for implementation and co-ordination of mapping and research within geologically defined units of the Shield (Figure 2). The individuals within each subsection will continue to carry out their own mapping projects, but this will be co-ordinated with programs drawn up at the subsection level.

The authors are associated with the Central Archean subsection which covers the Quetico, Wabigoon and a part of the English River Belt (Figure 1).

The first task was to determine just exactly what was meant by the terms Quetico Belt and Wabigoon Belt, and indeed, the meaning of the word "Belt" itself.

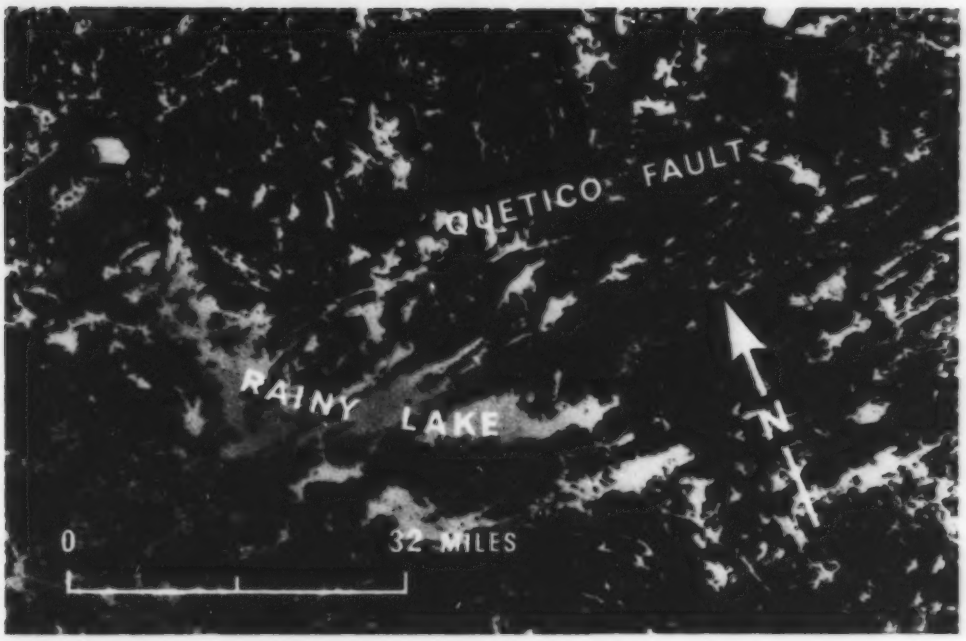
REGIONAL GEOLOGY

Following ideas put forward by Wilson (1949), Gill (1949) and others on the subdivision of the Canadian Shield, the belt concept was formalized by Stockwell (1964) who named major subdivisions of the Superior Province. Initially these were the Cross Lake, English River, and Quetico Belts. He defined these primarily on the basis of their internal structure, although he did give a brief lithological description of the English River and Quetico Belts. The Wabigoon Belt (Goodwin 1970), or the Keewatin Belt, as it was initially termed, was distinguished from the adjoining belts on the basis of differing internal structural style.

Previous workers have placed great emphasis on the structural nature of the belts, such as their structural trends, and their boundaries which have been stated to be zones of structural weakness, i.e. faults. It is suggested that such characterizations, with the over-emphasis on structure, tend to obscure the primary differences that exist between these belts.

The Quetico, Wabigoon, and English River Belts are primarily unique lithostratigraphic entities, which have been subjected to crustal and subcrustal modifications that are reflected geologically in their contrasting structural styles and metamorphic regimes, and geophysically in their contrasting aeromagnetic and gravimetric responses (Observatories Branch 1969; ODM-GSC 1970a,b).

The Quetico and English River Belts are an assemblage of metasediments and metasedimentary gneisses, migmatites, and granitic rocks of magmatic and anatectic origin. In contrast, the Wabigoon Belt is an assemblage of metavolcanic, volcaniclastic, and minor metasedimentary rocks that have been intruded by granitic rocks. The initial boundaries between these belts are thought to have been stratigraphic in nature and represented by a facies change from a predominantly volcanogenic to a predominantly epiclastic environment. Although these boundaries or interfaces are now locally marked by zones of structural weakness, e.g. the Quetico Fault (Figure 3), it is suggested that such structures are primarily the result of tectonic overprinting with major dislocation occurring along areas of lithologic discontinuity.



3. The Quetico Fault, as an east-west linear feature, on ERTS imagery. Detail from E-1166-16370, Band 6, 5th January, 1973.

Although stratigraphic relationships have been locally obscured by structural dislocations, it is feasible that the Quetico Belt was originally a depositional trough or basin that was infilled with metasediments derived by erosion from rocks of the Wabigoon Belt (Ayres 1969). It is not necessary to envision an ancient granitic craton as a source for sediments in the Quetico and English River Belts. Much of the material that forms the metasediments probably was derived by erosion of intermediate to felsic volcanic piles and associated subvolcanic intrusive bodies within a predominantly volcanic terrain (Mackasey 1972; Callander 1970).

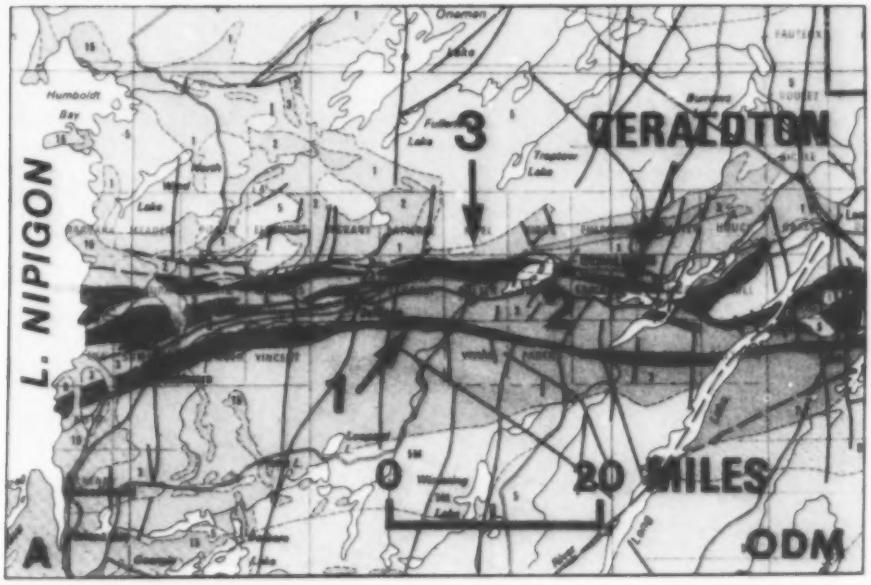
WABIGOON AND QUETICO BELTS

For a specific discussion of the nature of the boundary between belts, the Wabigoon Belt and Quetico Belt Interface has been chosen. The boundary between the English River and Wabigoon Belts is not discussed as it is at present only tenuously defined due to a lack of critical information.

4. Location map for Figures 5, 7, and 8. Adapted from Map 2199, West Central Sheet, Ontario Geological Map.

In the Beardmore-Geraldton area (Figures 4 and 5) the boundary between the Wabigoon and Quetico Belts is stratigraphic (Ayres 1969; Mackasey 1974b). There is no evidence to indicate that a major structural break exists. The stratigraphic assemblage consists of three main components: 1) a southern mafic lava unit adjoining the Quetico metasedimentary sequence; 2) a greywacke unit and related sedimentary rocks; and 3) a northern metavolcanic sequence. The relationships between these units are consistent for a distance of over 70 miles along strike. The sediments thin and become coarse-grained toward the volcanic pile to the north. Volcanic rocks thin and pinch out to the south (Figure 6).

Aeromagnetic data (ODM-GSC 1970a) indicate that these units continue beneath Lake Nipigon southwest to the Lac des Mille Lacs area where these units are truncated by the Quetico Fault.

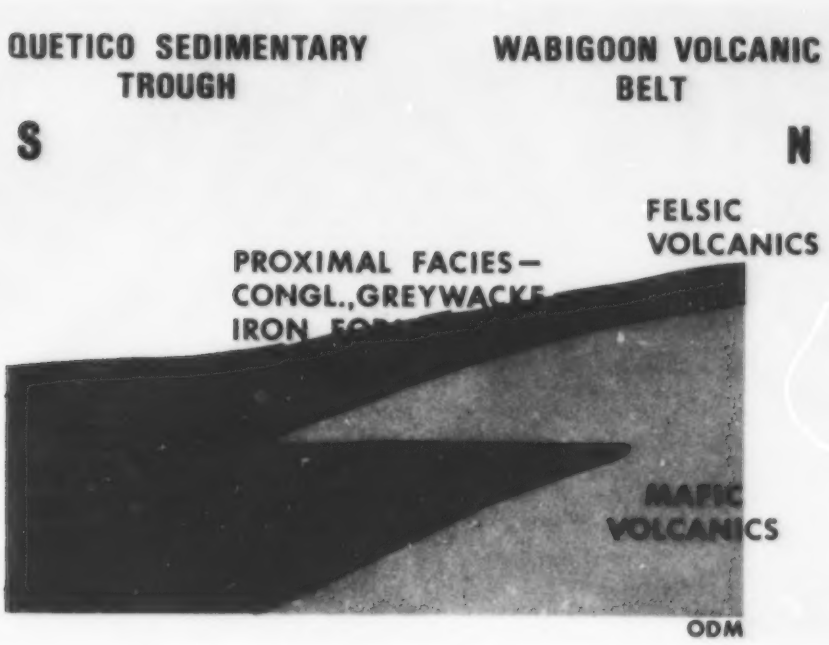


5. Geology of the Beardmore-Geraldton area. The large numbers (1,2, and 3) indicate major stratigraphic components described in the text.

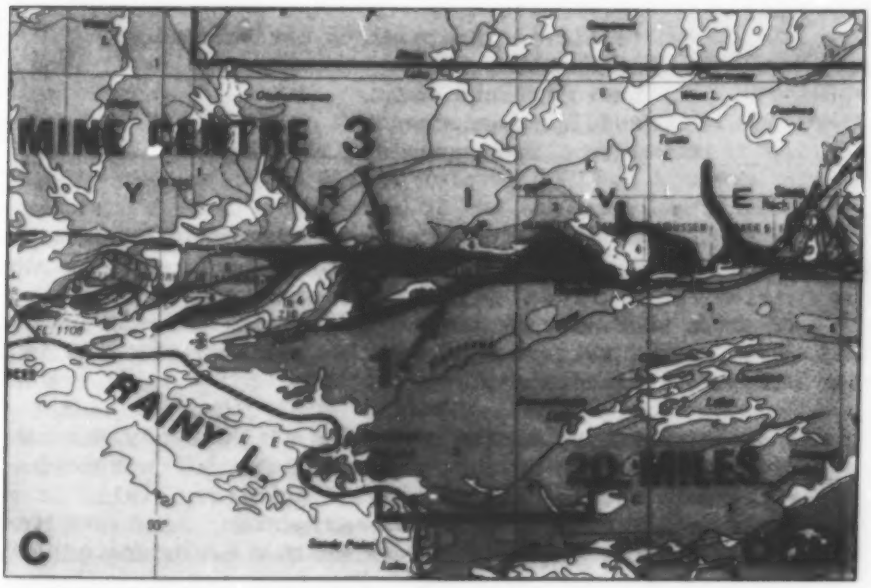
Map legend:
1. mafic metavolcanics
2. felsic to intermediate metavolcanics
3. metasediments
4. mafic igneous rocks
5. felsic igneous rocks
15. late mafic igneous rocks (Logan sills)

The thin slice of metavolcanics in the vicinity of Athelstane Lake is most likely the same southern mafic lava unit that is found elsewhere to the east along the Wabigoon-Quetico boundary. If interpreted in this manner all three stratigraphic units are present.

To the west along the Quetico Fault the same stratigraphic relationships are present in the Mine Centre area (Figures 4 and 7), i.e. a central metasedimentary sequence is bounded by two mafic metavolcanic units. Horizontal movement along the Quetico Fault has been demonstrated to be primarily right-lateral (Hawley 1929; Davies 1973a). Also, it appears that between Mine Centre and Lac des Mille Lacs parts (Figure 8) of the Wabigoon-Quetico Interface have been removed by horizontal and vertical dislocation along the fault. It is suggested, therefore, that

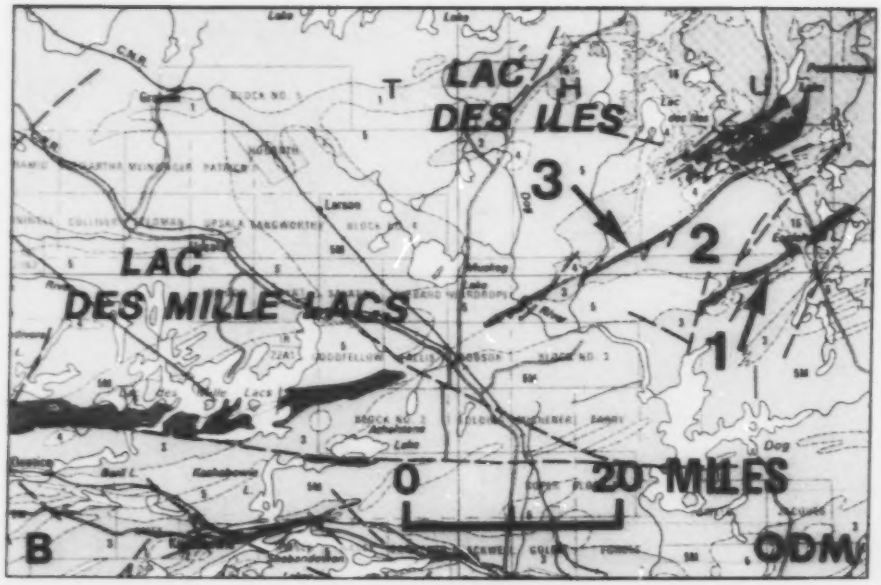


6. Diagrammatic cross-section through the Wabigoon-Quetico Interface (before folding), Beardmore-Geraldton area. Adapted from Ayres (1969).



7. Geology of the Mine Centre area. The large numbers (1,2, and 3) indicate major stratigraphic components described in the text.

Map legend:
1. mafic metavolcanics
2. felsic to intermediate metavolcanics
3. metasediments
4. mafic igneous rocks
5. felsic igneous rocks
15. late mafic igneous rocks (Logan sills)

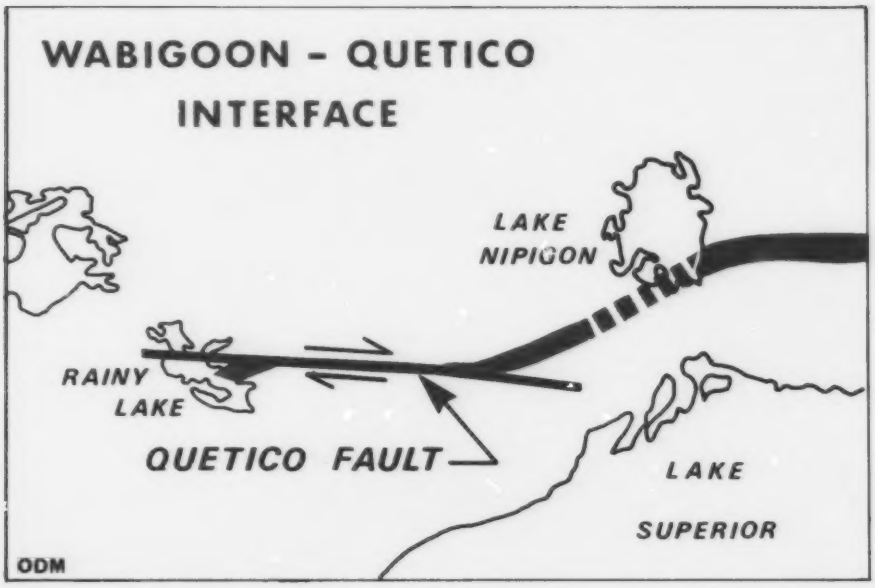


8. Geology of the Lac des Iles and Lac des Mille Lacs areas. The large numbers (1,2, and 3) indicate major stratigraphic components described in the text.

Map legend:
1. mafic metavolcanics
2. felsic to intermediate metavolcanics
3. metasediments
4. mafic igneous rocks
5. felsic igneous rocks
15. late mafic igneous rocks (Logan sills)

the original lithostratigraphic continuity of the Wabigoon-Quetico Belts has been dislocated by large-scale right-lateral horizontal displacements along the Quetico Fault (Figure 9). This reconstruction is a hypothesis only, but exercises such as this are important both in understanding the geological evolution of this part of the Superior Province and in evaluating its economic implications.

Several models relating to the evolution of the early Archean crust were reviewed in preparation of this paper. Classical geosynclinal concepts, plate tectonic models, and rifting of primitive sialic crust with the evolution of linear metavolcanic-metasedimentary complexes have all been used in recent years as tentative models for early crustal development.



9. Sketch-map showing suggested displacement of the Wabigoon-Quetico Interface by right-lateral movement on the Quetico Fault. Interface shown in stipple.

To come to an understanding of the nature of the primitive crust and subsequent crustal evolution, comparisons have been made between such well-known areas as the Barberton Mountain Land and Rhodesian Cratons (Anhaeusser 1973), the Greenland-North Atlantic region (Bridgewater et al. 1973), and Australian Archean cratonic blocks (Glover 1971). A number of areas in the Superior Province, including parts of the Wabigoon Belt, have been compared to these areas and attempts have been made to fit them into suggested evolutionary models.

Upon examination of available data, specifically that of a quantitative nature for the Wabigoon Belt, it is felt that such comparisons, although valid on a multi-hypothesis level, are invalid on the level of a working model. Within the Wabigoon Belt itself, large scale correlations based on comparison of lithology and paleoenvironment have tended to overshadow the uniqueness of the individual metavolcanic-metasedimentary complexes.

In light of our reconstruction of the Wabigoon-Quetico Interface, and the emphasis placed on stratigraphy, it becomes more apparent that the metavolcanic-metasedimentary assemblages of the Wabigoon Belt show a pronounced northeast alignment. These are, in fact, two broad northeasterly trending

lithologic units, one extending from Lake of the Woods northeast to Savant Lake, the other from Atikokan through to the Marshall Lake or even the Melchett Lake areas. Whether these two units developed simultaneously or progressively is not known. Now they are separated by a large area underlain by granitic rocks. A west-southwest-trending gravity high (Observatories Branch 1969) overlies a part of this granitic zone between Caribou and Obonga Lakes. The projected continuation of this trend is approximately collinear with the Cape Henrietta-Maria Arch in the James Bay Lowlands.

MINERAL EXPLORATION

Gold

Although the authors cannot predict future world economic conditions it is clear that at present gold is an active commodity. While there are no mines presently in operation in the area, gold prospects, specifically past producers within the Wabigoon Belt, are now receiving increasing attention, e.g. the re-examination of the old Duport Mine in the Lake of the Woods (Beard 1974) and the work of Consolidated Louanna Gold Mines Limited at O'Sullivan Lake (Fenwick 1972) (Figure 10). Past producers and gold prospects are being re-examined and if not held under patent are in many instances being restaked.

Results of a study of forty-two past producing mines (Ferguson et al. 1971) are shown in Figure 11. As indicated by the bar graph, a major proportion of the mines are situated within the mafic metavolcanics. From this observation it could be concluded that exploration programs would best be directed to volcanic areas. However, the bar graph shows that the most important gold production, by far, has come from areas of metasediments. Specifically, these are from metasediments along the Wabigoon-Quetico Interface in the Beardmore-Geraldton area.

The authors think that the initial source for gold was the mafic volcanic and associated mafic intrusive rocks, as has been suggested for the Early Precambrian of Southern Africa by Viljoen et al. (1971). In the Lake of the Woods area through to Wabigoon Lake there appears to be a spatial relationship of both copper and gold occurrences to mafic and even ultramafic intrusive bodies (Davies et al. 1967).

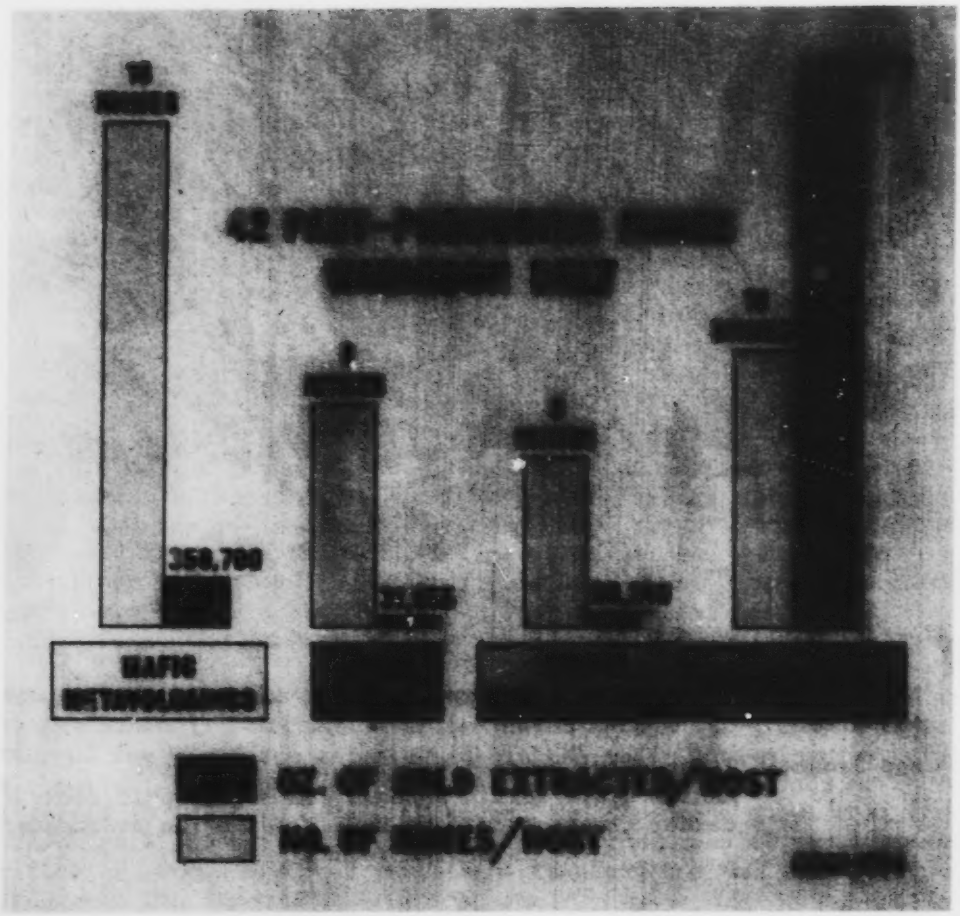
Felsic intrusive rocks, rather than being the source of gold in mafic volcanic areas, acted instead as concentrating agents. They were sources of heat, volatiles, water, and silica that extracted gold from the surrounding volcanic rocks. Their intrusion also produced favourable structural sites for gold deposition. A clue to whether a specific felsic intrusion and (or) its host rock is a possible exploration target for gold would be the presence of extensive alteration zones. The St. Anthony gold mine at Sturgeon Lake (Trowell 1974) may be an example of this type of gold deposit.

10. Location map of selected gold deposits Wabigoon Belt. Belts outlined in white.

    Map legend: light grey- volcanic-sedimentary complexes
    medium grey- felsic igneous and metamorphic rocks
    darker greys- Middle to Late Precambrian sedimentary and intrusive rocks.

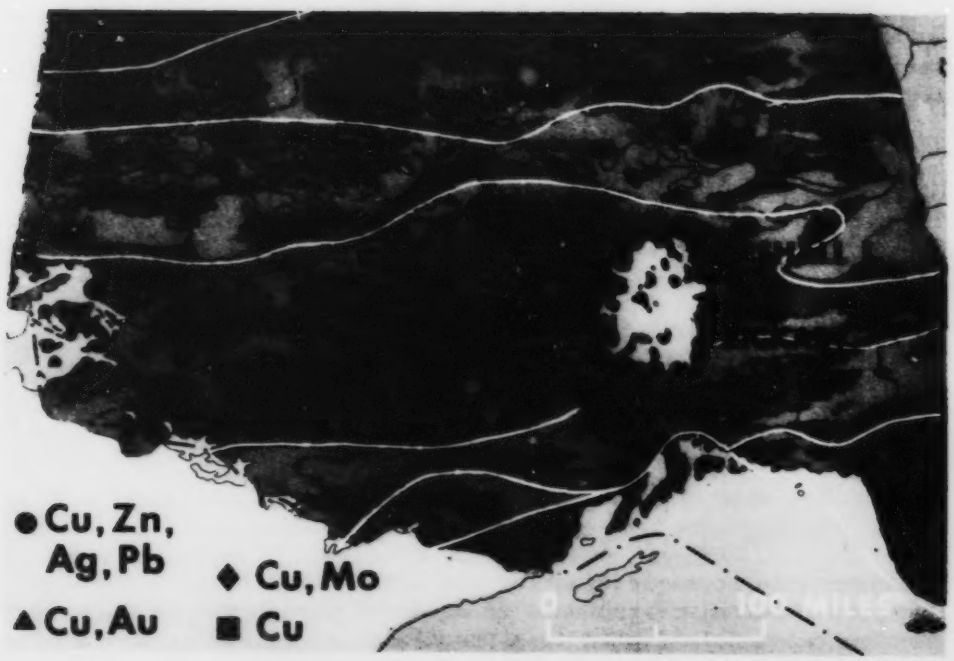
Commonly, gold occurrences located within and therefore thought to be directly related to granitic intrusions are, on close examination, found to be associated with xenoliths of mafic volcanics and related hybrid zones. A possible example is the Hammond Reef Mine north of Atikokan (Fenwick 1972).

Another association that has been presented in the past is that of gold and iron formation (Ridler 1973). Some iron formations appear to have been formed in an environment that was also suitable for the simultaneous deposition of gold. However, it appears that the gold has to be concentrated by some process for economic deposits to form. This concentration may be accomplished by intrusion of felsic stocks and dikes into the iron formation, or it may be accomplished by mechanical deformation that provides the thermal energy required for gold concentration. A possible example of the latter type is the Leitch Gold Mine (Mackasey 1974a).



11. Bar graph of gold production and number of mines plotted against host rock type, Wabigoon Belt.

Many gold occurrences associated with quartz veins may represent reconstituted stratigraphic siliceous exhalative deposits. Examples of this type are present within many metavolcanic-metasedimentary assemblages. They are apparently cross-cutting gold-bearing quartz veins accompanied by a variety of carbonate minerals, pyrite, chalcopyrite, tourmaline, and fuchsite. These deposits may in fact represent stratabound chemically precipitated units which have been structurally dislocated and reconstituted due to an influx of water and volatiles. Examples of this type may be the Brookbank and Northern Empire deposits near Beardmore (Mackasey 1971; 1974d).



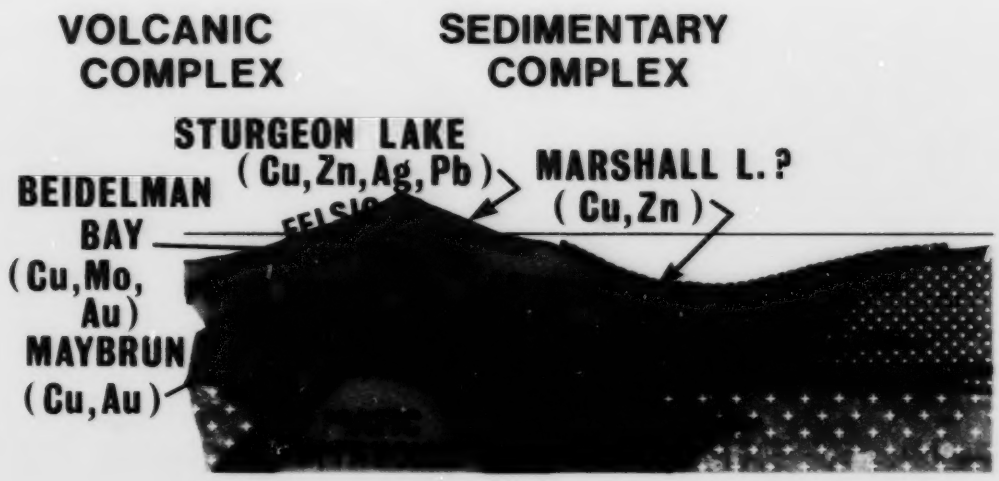
12. Location map of selected base-metal sulphide deposits, Wabigoon and Quetico Belts.

Map legend: light grey- volcanic-sedimentary complexes
medium grey- felsic igneous and metamorphic rocks
darker greys- Middle to Late Precambrian sedimentary and intrusive rocks.

Once a particular lithology has been selected as an exploration target for gold mineralization, the search may be narrowed down to those areas where felsic intrusions and (or) complex structural deformation have disrupted the country rocks.

Base-Metal Sulphide Deposits

Figure 12 shows the distribution of base-metal sulphide deposits and significant occurrences within the Wabigoon Belt. Figure 13 places selected deposits in their geological environment.



13. Diagrammatic cross-section through hypothetical volcanic-sedimentary complex showing environments of selected base-metal sulphide deposits. Geological model adapted from Hutchinson et al. 1971.

Although the Maybrun and Sturgeon Lake deposits are considered to be volcanogenic in origin, the two are distinct with respect to metal abundances and volcanic environment. The Maybrun deposit is a copper-gold deposit associated with a basal assemblage of pillowed mafic metavolcanics (Davies 1973b). The Sturgeon Lake zinc, copper, silver, and lead deposits are associated with the lower intermediate to felsic, predominantly pyroclastic members of a multicyclic, metavolcanic assemblage (Trowell 1970; Northern Miner 1969b; 1970a,c; 1971a,b; 1972; 1973). The Sturgeon Lake deposits are themselves stratigraphic units and exhibit volcano-sedimentary features comparable to the Kuroko deposits of Japan (Tatsumi 1970). The Maybrun deposit appears to be disseminated, although future investigations may prove a possible stratigraphic control over its distribution.

Within these metavolcanic-metasedimentary complexes the distinction between pyroclastic, volcaniclastic, and epiclastic rocks is of critical importance in delineating areas of possible economic significance. Pyroclastic and volcaniclastic rocks near volcanic centres are the more favourable environments for localization of base-metal sulphide mineralization. Proximal facies epiclastic rocks could possibly act as hosts to base-metal sulphide deposits under certain environmental conditions within the sedimentary basin. The occurrences at Marshall Lake (Langford 1958; Pye et al. 1966) may fall within this class.

Another factor is the possibility of mass movements of sulphide deposits by gravity slides or slumps (Jenks 1971) whereby the sulphide mass may retain its coherence as a physical entity but would be separated from its depositional environment and thus foreign to its present host. Exploration for deposits such as these is probably best confined to volcaniclastic rocks of laharic or turbudite origin, intimately associated with volcanic complexes. The possibility of large scale mass movements or slumps would suggest that the marginal facies of the English River and Quetico Belts could contain similar deposits.

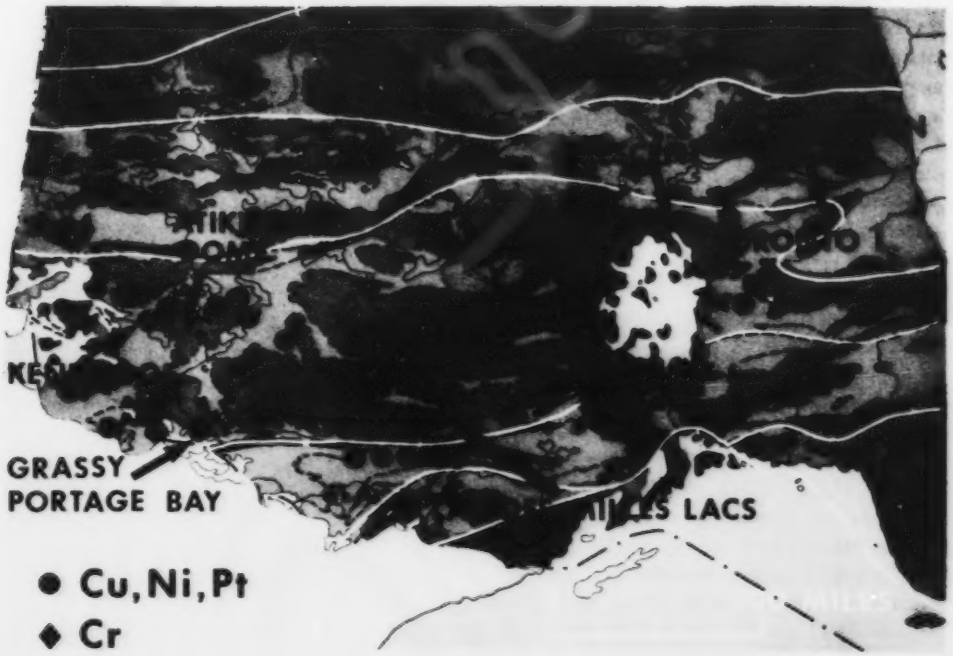
The subvolcanic porphyry intrusions with their associated copper, molybdenum, and gold mineralization are thought by the authors to be integral components of the metavolcanic-metasedimentary complexes. They may be important both in defining the centres of these complexes, thus outlining favourable exploration areas, and in their possible genetic relationship to volcanogenic massive sulphide deposits. In essence these bodies were sources of thermal energy, water, and volatiles. During the evolution of specific types of subvolcanic porphyry bodies, a fluid phase enriched in various metals may have formed. This phase would subsequently have been expelled during the waning stages of a particular volcanic cycle. Whether significant economic concentration resulted would depend upon the environment into which this metal-rich fluid was expelled.

There are porphyries and porphyries. Those porphyries which consist of multiple intrusive phases, such as the Beidelman Bay subvolcanic complex at Sturgeon Lake (Trowell 1970), are important both for their possible porphyry-type copper and molybdenum potential within the complex, as well as for the possibility of having associated base-metal sulphide deposits.

Only brief mention will be made of some of the other occurrences shown of Figure 13. A disseminated copper-zinc deposit occurs in the felsic breccias and flows in Rickaby Township and appears to be of volcanogenic origin (Mackasey et al. 1974). Copper-bearing pyritic deposits are present in north-trending late-stage breaks east of Lake Nipigon in the Barbara Lake area (Pye 1970). The sulphide mineralization is confined to breccia zones within these breaks, and may in part be similar to Tribag-type breccia deposits (Blecha 1965, 1973; Giblin 1966).

Mafic and Ultramafic Rocks

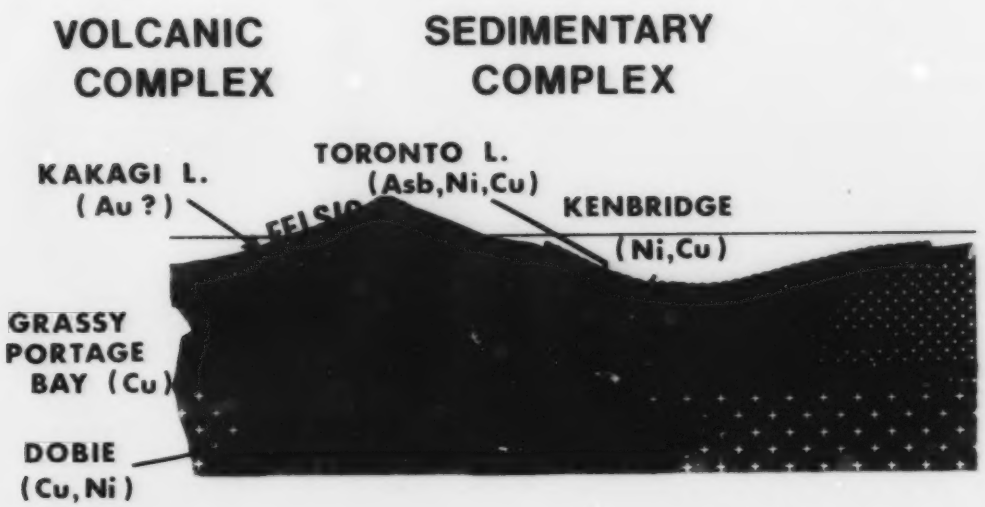
Numerous bodies of mafic to ultramafic rocks lie within the Quetico and Wabigoon Belts (Figures 14 and 15). Those bodies which contain significant copper, nickel, and platinoid occurrences are shown in Figure 12. The mineralized zones also can occur within the rocks these bodies intrude. However, the intrusions themselves appear to be the source of the mineralization. The host rocks may contribute certain components such as sulphur, volatiles, and aqueous fluids that may assist in the localization of the mineralization.



14. Location map of selected deposits in mafic and ultramafic intrusions, Wabigoon and Quetico Belts.

Map legend: light grey- volcanic sedimentary complexes
medium grey- felsic igneous and metamorphic rocks
darker greys- Middle to Late Precambrian sedimentary and intrusive rocks.

Several small ultramafic bodies lie within the Quetico Belt marginal to the Quetico Fault between Steep Rock Lake and Lac des Mille Lacs (Pye et al. 1965). If these bodies are associated with the Quetico Fault, there may be similar bodies to the east through to the Dog Lake area, along and south of the extension of the Quetico Fault. These bodies all carry nickel and nickel-copper mineralization locally accompanied by platinoid group metals (Irvine 1963; Hawley 1929). It is of interest that the iron formation at the original Atikokan Iron Mines, which lies along the Quetico Fault, occurs as massive magnetite-sulphide lenses within an altered gabbro body; nickel and copper mineralization were locally reported from these lenses (Hawley 1929).



15. Diagrammatic cross-section through hypothetical volcanic-sedimentary complex showing environments of selected deposits in mafic and ultramafic intrusions. Geological model adapted after Hutchinson et al. 1971.

The main intrusions south of the Quetico Fault in the Rainy Lake area vary in composition from gabbro-norite to anorthosite with local irregular zones of pyroxenite and hornblendite. Mineralization comprises copper and copper-nickel with no reported platinoid group minerals (Davies 1973a; Harris 1970). Several copper showings, locally with trace nickel are associated with the Grassy Portage Bay Sill (Harris 1970). West of Mine Centre a gabbro-anorthosite body contains zones of titanium-rich magnetite which possibly formed as crystal cummulates during differentiation of the body (Lister 1966).

In the Lake of the Woods-Wabigoon Lake area there are two broad groupings of mafic to ultramafic bodies. Gabbro-diorite-anorthosite bodies, locally accompanied by variable amounts of ultramafic material, occur as sills and plugs confined mainly to the lower mafic metavolcanic assemblages. These bodies carry copper and copper-nickel mineralization, e.g. the Kenbridge property (Davies 1973b). These bodies may have been the source of the copper mineralization within the adjacent mafic metavolcanic rocks which they intrude. A number of these types of occurrences are marginal to the Atikwa batholith (Davies 1973b) which is a possible exploration target.

The second grouping comprises a series of differentiated ultramafic sills and plugs which occur higher in the metavolcanic secession, e.g. the differentiated sills at Kakagi Lake, which lie within the felsic metavolcanic sequence (Morin 1973; Kay 1973). These bodies appear to have associated gold occurrences the origin of which is unknown.

From O'Sullivan Lake in the east through to Crescent Lake in the west several mafic and ultramafic bodies lie within and near to the north margin of the Wabigoon Belt. A sulphide occurrence is reported from a differentiated sill at O'Sullivan Lake (Moorhouse 1955) but at Toronto Lake mafic and ultramafic rocks have associated asbestos and nickel-copper mineralization (Northern Miner 1969a; 1970b; Pye 1968).

In the Obonga Lake area an ultramafic body carries nickel-copper mineralization accompanied by minor platinoids (Kustra 1967a,b; Simpson et al. 1967). The nearby Chrome Lake chromite deposit, which is unique in the Wabigoon Belt (Kidd 1934; Kustra 1967a,b) is thought to have been intruded as a cold ultramafic mass along major thrust zones (C.R. Kustra, Ontario Division Mines, personal communication). This deposit falls into a strategic category, being one of the few chromite deposits in Ontario.

Alkalic Complexes

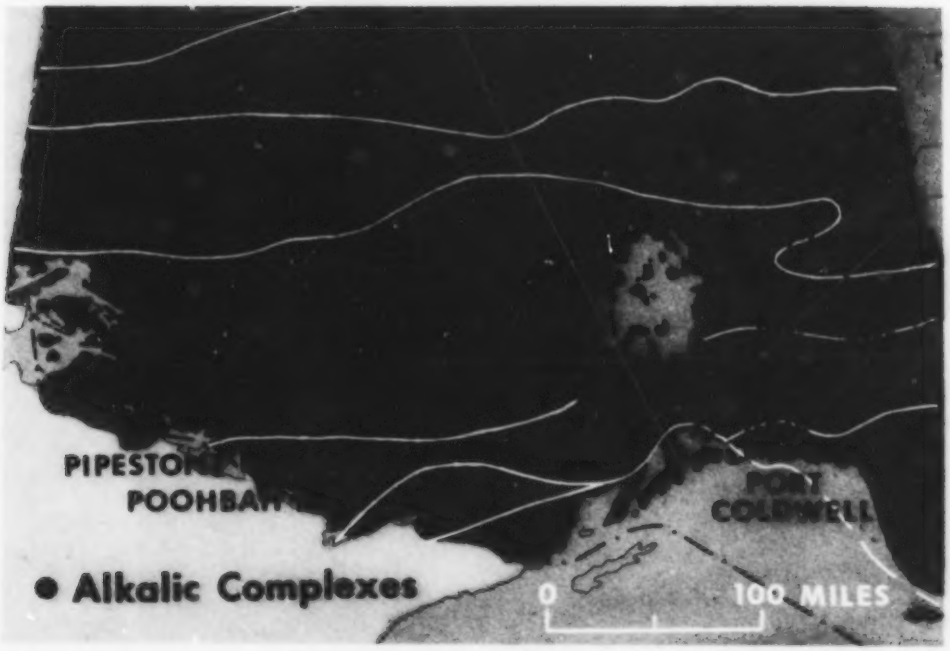
There are three general locations of alkalic complexes in the area under consideration (Figure 16).

In the west, the Poohbah Lake complex lies within the Quetico Belt (Lawson 1896; Satterly 1970), and the Sturgeon Narrows and Squaw Lake complexes at Sturgeon Lake (Satterly 1970; Trowell 1972a,b; 1973), occur within the Wabigoon Belt.

Reference should be made to two pronounced circular magnetic anomalies located west of Poohbah Lake in the Pipestone River area (ODM-GSC 1970a) which possibly signify the presence of alkalic complexes or mafic to ultramafic intrusive bodies.

In the east, the Prairie Lake (Satterly 1970; Watkinson 1974), Killala Lake (Coates 1967; 1970; Satterly 1970), and Chipman Lake complexes are aligned to the south with the Coldwell complex (Puskas 1967) (Figure 17). It is suggested that there may be an undiscovered alkalic complex near McKay Lake, where a circular magnetic anomaly is masked by the aeromagnetic response of the iron formation in the area (Figure 18). This anomaly is in line with the trend of the other complexes.

The majority of the world's alkalic complexes are generally found confined to stable crustal areas where they demarcate zones of tensional



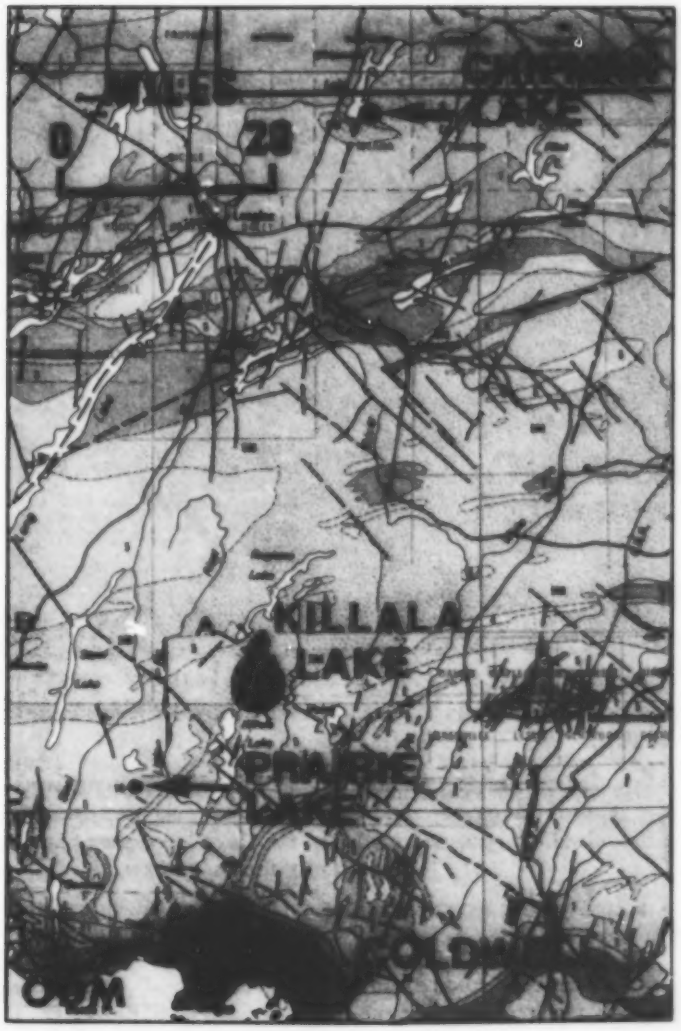
16. Location map of known and postulated alkalic complexes, Wabigoon and Quetico Belts.

Map legend: light grey- volcanic-sedimentary complexes
medium grey- felsic igneous and metamorphic rocks
darker greys- Middle to Late Precambrian sedimentary and intrusive rocks.

fracturing or incipient rifting. Thus these bodies are of critical importance in understanding the crustal evolution of this area as well as being individually important for their economic potential in base-metals, rare earth elements, and other commodities.

CONCLUSIONS

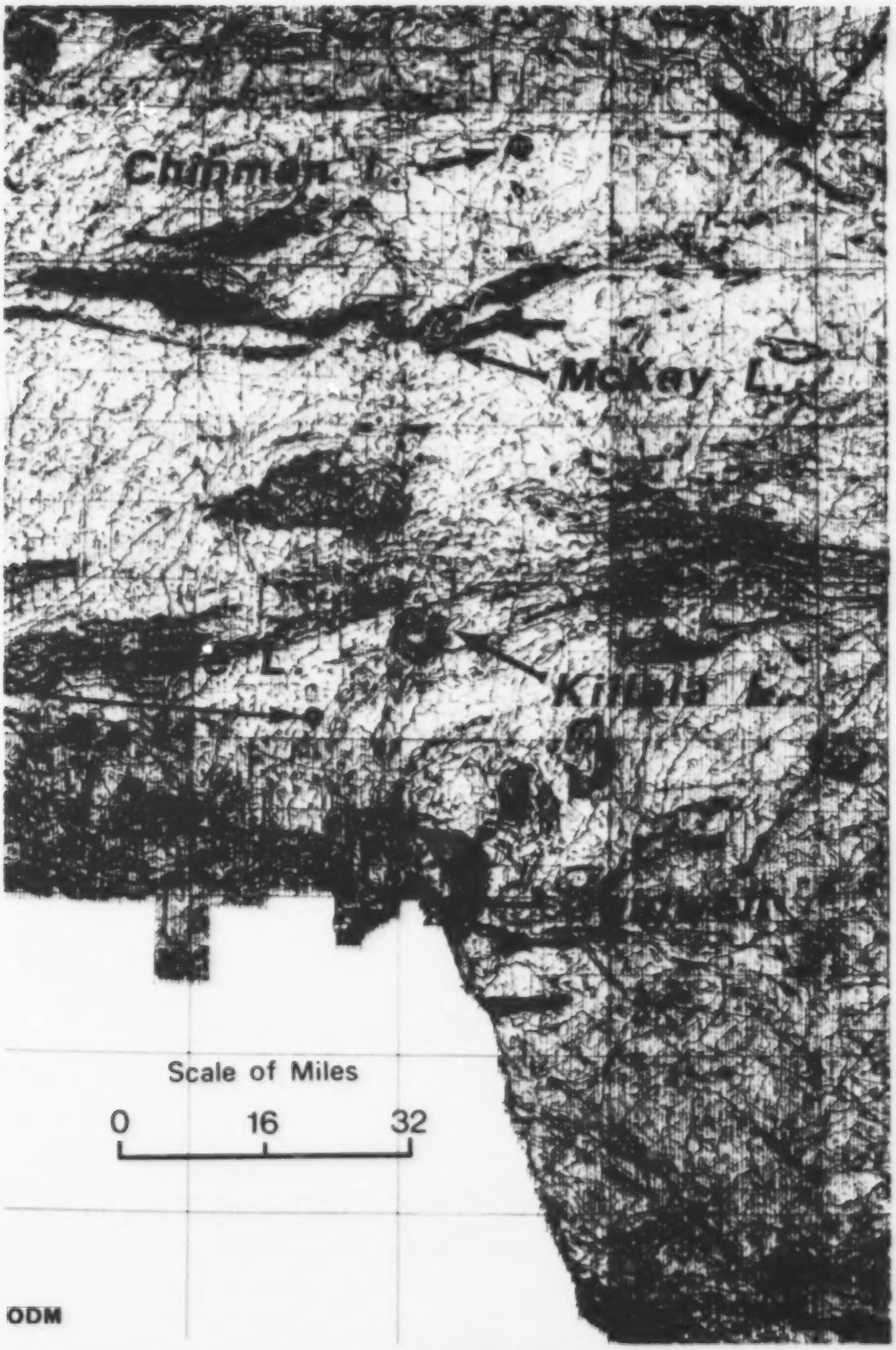
In summary it is apparent that the Wabigoon Belt may have originally been two separate northeasterly trending volcanic zones. Any east-west correlation, whether for economic or academic reasons, should take this into account. Sedimentary assemblages along the Wabigoon-Quetico Interface have yielded the best gold production. It is recommended that this area is still worthwhile for continued gold exploration. Because of the interpretation of the faulted-off extension of the Wabigoon-Quetico Interface near Mine Centre, the authors suggest that the metasediments in this area merit attention. At present the Geological Branch is conducting a geochemical pilot study on glacial tills for application to gold exploration.



17. Location map of known alkalic complexes north of Lake Superior. Detail of Map 2199, West Central Sheet, Ontario Division of Mines.

Map legend:

1. mafic metavolcanics
2. felsic to intermediate metavolcanics
3. metasediments
4. mafic igneous rocks
5. felsic igneous rocks
15. late mafic igneous rocks (Logan sills)
16. carbonatite-alkalic complexes



18. Detail of aeromagnetic map P.578 showing anomalies over known alkalic complexes and over McKay Lake, north of Lake Superior.

In the past, exploration for base-metals has tended to be confined to areas of felsic metavolcanics. However, the Maybrun Mine shows that mafic metavolcanic rocks should not be ignored.

The authors' speculation that an alkalic complex may exist near McKay Lake is important from the viewpoint of the economic mineral potential of the alkalic rocks within this zone.

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Although the ideas here presented may differ from those previously stated by other workers, it is only the excellent background of information supplied by previous individuals and organizations that allows us to present our thoughts and interpretations.

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